INTERIM RECOMMENDATIONS

ON

DOSES TO PERSONS EXPOSED

TO TRANSURANIUM ELEMENTS

IN THE GENERAL ENVIRONMENT

U.S Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

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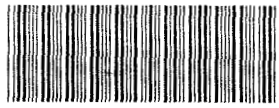
INTERIM RECOMMENDATIONS:
DOSE LIMITS FOR PERSONS EXPOSED TO TRANSURANIUM ELEMENTS
IN THE GENERAL ENVIRONMENT



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EXECUTIVE SUMMARY

The Environmental Protection Agency, in consultation with other Federal agencies, has developed interim recommendations to be used for protection of public health in areas where significant contamination by plutonium and other transuranium elements now exists or may occur in the future. These interim recommendations provide uniform guidance to all agencies of the Federal government on limiting radiation doses to persons exposed to transuranium elements in the general environment until such time as final recommendations are provided. The recommendations provide a range of dose rate limits and corresponding action levels as a guide for site-specific actions.

The interim recommendations were developed by the Environmental Protection Agency (EPA) under authority of Executive Order 10831 and Public Law 86-373 (42 U.S.C. 2021(h)), as transferred to the Environmental Protection Agency by Reorganization Plan No. 3 of 1970. These require that the Administrator of the Environmental Protection Agency "...advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards, and in the establishment and execution of programs of cooperation with States."

The interim guidance adopts the current views on risk reduction by national and international radiation protection organizations, specifically extends the recommendations of Federal Radiation Guidance No 2 for internal emitters to the transuranium radionuclides, and presents a summary of the vast amount of additional technical information for the transuranium radionuclides that has become available recently.

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INTERIM RECOMMENDATIONS

In order to assist in the evaluation and determination of possible remedial actions for concentrations of transuranium elements present above average background levels in the general environment, the Environmental Protection Agency is providing the following interim recommendations for the guidance of Federal agencies:

1. Federal agencies should assess environmental contamination by the transuranium elements in terms of its potential effects on people. The objective of remedial actions should be to assure both that the radiation protection guides are not exceeded and that the individual and collective doses to the exposed population over the time of persistence in the environment be as-low-as-reasonably-achievable (ALARA). Remedial actions for contaminated sites should be implemented with the objective of minimizing adverse impacts on the environment.

2. The recommendations should be implemented by the Federal agency under whose jurisdiction the facility which caused the environmental contamination operates, or of the Federal agency whose operations otherwise cause the environmental contamination. Implementation includes determining both the actual or potential hazard to people and instituting remedial actions where required.

3. The Federal agency responsible for implementation should develop a range of options for remedial actions which are expected to control radiation exposures to persons in the general population in accord with these recommendations. The expected reduction in health risks, feasibility of implementation, and total costs should be evaluated for each option.

4. A radiation protection guide (RPG) whole-body dose equivalent limit to an individual in a critical segment of the general population of 100 mrem/yr (1 mSv/yr) from all sources (not including natural background and medical radiation) is appropriate for implementing the recommendations for environmental contamination by transuranium elements.

5. In order to assure that exposures of individuals not exceed a small fraction of the radiation protection guide specified in Recommendation 4, the added annual alpha radiation dose rate to members of the critical segment of the exposed population from transuranium elements in the general environment should, to the extent practicable, be limited to:

a. 1 millirad (10 uGy) per year to the pulmonary lung, or
b. 3 millirad (30 uGy) per year to the bone*

Projected dose rates as specified above are designated as Range I.

(* Note: An equivalent dose rate to endosteal bone surfaces or to red bone marrow, as defined by ICRP Publication 26, may be used)

6. Radiation dose rates to persons in the critical segment of the population greater than those specified for Range I and less than the applicable radiation protection guide specified in Recommendation 4 are designated as Range II. Projected dose rates within Range II are consistent with these recommendations, provided that the responsible agency has determined that the risks to the exposed population are justified, established that individual and collective radiation doses are as-low-as-reasonably-achievable (ALARA), made all reasonable efforts to reduce exposures, and implemented appropriate protective measures. Monitoring and surveillance of a population in Range II areas should be designed to establish a base case and projection of future trends for the principal environmental pathways.

7. Short-term or intermittent whole-body dose equivalent exposures to persons in the critical segment of the population should not exceed 500 mrem (5 mSv) from all sources combined in any year. Dose rates greater than the radiation protection guide and less than 500 mrem/year on an intermittent basis are designated as Range III.

8. The radiological control activities of Federal agencies in connection with environmental contamination by transuranium elements should be implemented by the following scale of protective actions related to the dose rates and associated risks to exposed persons in the general population:

	Residual Contamination Levels Equivalent To:	Implementation Actions
Range I	projected dose rates at or below: 1 mrad/yr to pulmonary lung, or 3 mrad/yr to bone	unrestricted occupancy without continuing surveillance; monitoring and reviews sufficient for reasonable confirmation
Range II	projected dose rates greater than Range I and not to exceed Radiation Protection Guide (100 mrem/yr WBEq)	general surveillance and routine monitoring; implementation of ALARA
Range III	projected dose rates greater than those for Range II (not to exceed 500 mrem/yr on an intermittent basis)	continuing monitoring and evaluation of individuals; access and/or use limitations pending implementation of permanent remedial actions

Federal agencies responsible for implementation should provide for adequate long-term public health protection by designating specific action levels for sites (or portions of sites) in terms of dose or risk to persons in the critical segment of the population based on residual contamination levels of the transuranium elements, and by maintaining appropriate monitoring, restrictions, or other controls. Site-specific criteria may be developed in conformance with these general guidelines, with due consideration to the requirement of protection of that segment of the population at greatest risk. Classification of an area should be reviewed periodically and changed as required.

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9. Federal agencies should apply the recommendations only to the transuranium elements and only to existing or possible future environmental contamination as defined below. It is not appropriate to use the numerical dose rate limits, or any other limits derived from these, and apply them to any other radionuclides. The recommendations should not be used by Federal agencies as general criteria for decontamination or decommissioning activities of sites or facilities.

10. The recommendations are limited to evaluation and possible remedial actions appropriate to stabilized contamination. They do not apply to the transient period during and immediately following an accident when protective actions generally defined by emergency response criteria are appropriate. For newly contaminated areas, the Federal agency responsible for implementation of these recommendations should take immediate action to minimize the residual levels of transuranium elements in the general environment or within restricted areas and to limit the radiation exposure of the general public. Releases equal to or greater than the reportable quantities published under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, must be reported to the National Response Center. Determination and implementation of further appropriate measures, to ensure that projected dose rates to persons in the general population are as-low-as-reasonably-achievable and in full compliance with the above recommendations, should begin as promptly as possible and should be completed within a reasonable period of time.

11. The recommendations are applicable only to presently existing cases of environmental contamination by transuranium elements and to possible future incidents of environmental contamination from unplanned releases of transuranium elements. Federal agencies should not use them as limits for planned releases of transuranium elements into the general environment.

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12. The recommendations may be applied to all areas which are not otherwise excluded by administrative actions, and include all unrestricted areas outside the boundaries of a Federally owned, operated, or licensed radiological facility.

13. Remedial actions should accomplish a permanent, rather than short-term, reduction in the potential risk to persons in the general population. Restrictions on occupancy or land use should not be relied on to provide the necessary protection to future generations.

14. In determining appropriate remedial actions, Federal agencies should assure compliance with all applicable environmental standards and guides. Implementation of remedial actions should consider existing and possible future contamination of surface, groundwater, and drinking water supplies, and should apply reasonable measures to preserve preexisting water quality.

15. To facilitate implementation, numerical values for ambient soil or air concentrations of the transuranium elements which can be related to the dose rates given in these recommendations may be derived on a site-specific basis. For purposes only of eliminating certain lands from further more detailed evaluation, a soil contamination level of 0.2 uCi/m^2, for samples collected at the surface to a depth of 1 cm and for particle sizes under 2 mm, would establish a conservatively based "screening level" for this purpose. Similarly, an air concentration "screening level" of 1 fCi/m^3 for alpha-emitting transuranium nuclides (based on an activity median aerodynamic diameter (AMAD) of 1 um) may be used under most circumstances. Areas which do not exceed the "screening level" generally may be considered in compliance with the recommendations; those that exceed it would require more intensive evaluation to determine the actual dose rates to exposed persons. The "screening level" should not be interpreted by Federal agencies as a soil concentration limit for purposes of implementing these recommendations.

DEFINITIONS

"as-low-as-reasonably-achievable (ALARA)" means that all unnecessary radiation exposures be avoided and that radiation exposure of individuals and population groups be minimized, taking into account economic and social considerations (adapted from ICRP Publication 22).

"bone" means osseous tissue. The average total weight of this tissue is assumed to be 5,000 grams. The equivalent dose to "bone surfaces" as defined in Publication No. 30 of the International Commission on Radiation Protection is about twelve times the average dose to "bone".

"critical segment of the exposed population" means that group of persons within the exposed population who, because of residency or other factors, can on the average be expected to receive the highest lifetime radiation dose to the pulmonary region of the lung or to the bone from a specified source of transuranium element contamination.

"whole body dose equivalent" means the sum of the annual dose equivalents to organs multiplied by the weighting factor specified in ICRP Publication 26 and modified by the appropriate radiation quality factor.

"general environment" means the total terrestrial, atmospheric and aquatic environments outside the boundaries of Federally-licensed facilities or outside the boundaries of sites which are under the direct control of a federal agency.

"Gray (Gy)" is the unit of absorbed dose in the international system and is equal to 100 rad.

"millirad per year to the bone" means the dose rate attained in the 70th year of chronic exposure. This dose rate is calculated by dividing the alpha energy absorbed in the bone during the 70th year by the bone mass.

"millirad per year to the pulmonary lung" means the equilibrium dose rate for chronic inhalation. This dose rate is calculated by dividing the alpha energy absorbed per year in the pulmonary lung by the lung mass.

"pulmonary lung" means the region of the lung consisting of respiratory bronchioles, alveolar ducts, atria, alveoli, and alveolar sacs. The average total weight of this tissue, including the capillary blood, is assumed to be 570 grams.

"rad" is the unit of absorbed dose, defined as the energy imparted to tissue by ionizing radiation, divided by the mass of the tissue. One rad is equal to the absorption of 100 ergs of radiation energy per gram of matter.
To convert a dose rate given in millirad to millirem, the ICRP currently recommends that a Quality Factor of 20 be used for alpha (high LET) radiation (ICRP Report 30).

"Radiation Protection Guide (RPG)" is the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable (Federal Radiation Council Report No. 1)

"Sievert (Sv)" is the unit of dose equivalence in the international system (SI) and is equal to 100 rem.

"transuranium elements" means all chemical elements with atomic numbers greater than that of uranium as classified in the Periodic Table of Elements.

BACKGROUND INFORMATION

The Environmental Protection Agency, in consultation with other Federal agencies, has determined that there is a need for advice applicable specifically to environmental contamination by plutonium and other transuranium elements. The interim recommendations are intended to provide both a perspective on the health risk from existing contamination and a basis for protective actions in the event of a possible future accident.

General radiation guidance has been published, and provides the basis for these interim recommendations. The first memorandum from the Federal Radiation Council was approved by the President on May 13, 1960 and stated: 1) that there can be different Radiation Protection Guides with different numerical values, depending upon the circumstances, and 2) that every effort should be made to maintain radiation doses as low as practicable. The second memorandum from the Federal Radiation Council was approved by the President on September 20, 1961, and provided recommendations for internal emitters, specifically radium -226, iodine -131, and strontium -89 and -90. More recent recommendations have been provided by the International Commission on Radiological Protection. The interim recommendations extend these concepts specifically to the transuranium elements.

In view of existing and possible future environmental contamination by plutonium and other transuranium elements, and the substantial public concern about such contamination, the Environmental Protection Agency deems it desirable to publish interim recommendations at this time specifically for these radionuclides. This will establish the necessary basis for actions in the event of a release of transuranium elements to the environment, allow for advance planning, assure protection of potentially exposed persons, provide a comprehensive rationale for decisions on possible remedial actions, and establish uniform criteria for use by all Federal agencies. In order to allow time for further review, the Agency has decided to defer promulgation of final

recommendations for the following reasons: first, the complexity of the problem and the many uncertainties associated with implementation make it desirable to obtain some experience under a variety of conditions and solicit more comments in order to assure full consideration of all possible factors; second, the National Academy of Sciences has completed a study of the biological effects of alpha radiation, but it will require several years to review the results of their findings and develop a consensus on implementation; and third, the Agency is developing a general policy for risk management of carcinogenic substances, including criteria for all radionuclides. Although we do not expect these factors to significantly change the recommendations, deferring publication of final recommendations will allow for full consideration of all information, and provide for technical completeness and overall policy consistency. The interim recommendations will apply until they are superceded.

The Office of Radiation Programs of the Environmental Protection Agency initiated work on these recommendations in 1974. It held public hearings in Washington, D.C. in late 1974, and in Denver, Colorado in early 1975 to develop an information base for this program, and published a transcript of the proceedings. The Agency published a 'Notice of Proposed Federal Radiation Protection Guidance' in the Federal Register on Nov. 30, 1977 (Vol. 42, pp. 60956-9), and evaluated all comments received in response to this notice. Agency comments and supplementary information were published in EPA Technical Report 520/4-78-01 entitled "Response to Comments: Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment." A notice of availability of this document was published in the Federal Register Vol. 44, pp. 61104-5, Oct. 23, 1979).

Persons and organizations who responded to the request for comments on the proposed recommendations primarily questioned specific technical details, pointed out inadequacies as they saw them, asked for detailed information on the basis of the numerical recommendations, or suggested alternative implementation procedures. All comments were evaluated, technical experts were consulted as appropriate, and detailed responses were prepared.

As a result, the technical justification for the recommendations was greatly expanded, and these interim recommendations are substantially changed from the proposal.

Descriptive Information:

The transuranium elements have an atomic number greater than 92 and are radioactive. The principal transuranium element of concern is plutonium, which is produced in nuclear reactors and used in nuclear weapons and as fuel for fast-breeder reactors. Plutonium-239 is a very long-lived material with a radiological half-life of about 24,000 years. Other transuranium elements of importance include neptunium, americium, curium, and californium.

The transuranium elements, especially plutonium, have been recognized as potentially hazardous even in very small amounts. Mathematical models, based on an extensive data base, have been developed to predict the movement of the transuranium nuclides through the environment to man. The principal modes of intake are inhalation of resuspended materials previously deposited on soil surfaces and ingestion through drinking water and other parts of the food chain. Most of these radionuclides are alpha emitters and may cause lung, bone, or liver cancer when inhaled or ingested.

Present levels of the transuranium elements in the environment have resulted from several sources - regional and worldwide fallout from the testing of nuclear weapons in the atmosphere, accidents involving military and related operations, and local releases from nuclear facilities. The major portion of the transuranium elements in the environment is the result of surface and atmospheric nuclear weapons tests during the period 1945-1963. Atmospheric tests injected radioactivity into the stratosphere which has since then been slowly deposited more or less uniformly over the lands and oceans of the earth. As a result of these earlier weapons tests, the existing level of transuranium element contamination in soils of the United States is about 0.002 uCi/m^2. More recent weapon tests have not added significant amounts to this level.

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PERIODIC CHART OF THE ELEMENTS

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71 La* Series	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103 Act Series	(104)	(105)	(106)	(107)	(108)										

*Lanthanide Series	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
†Actinide Series	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102	(103) Lw

The transuranium elements (in shaded squares) are part of the actinide series of elements which as a group occupy a single square, at actinium (number 89) in the main figure. Plutonium, element 94, is in this series. The rare earth (lanthanide) series of elements, also shown on a horizontal row, also occupies a single square (at lanthanum, element 57) on the main chart.

Areas where there is substantial localized contamination above the general background level are well documented and extensive environmental analyses have been carried out at all these sites. The sites of highest contamination are, for the most part, on Federally owned property and access may be restricted. Table 1 shows estimates of the amount of plutonium in the environment at the major United States locations. More detailed information on the sources and current levels of the transuranium elements in the general environment is given in Volume II of the Technical Information Document.

Plutonium and other transuranium elements can move through the environment by a variety of transport mechanisms and pathways. These are determined by the chemical and physical form of the deposited material, the characteristics of the surface, local land use patterns, and other factors such as wind or rainfall. Principal environmental pathways to humans are shown in Fig. 1.

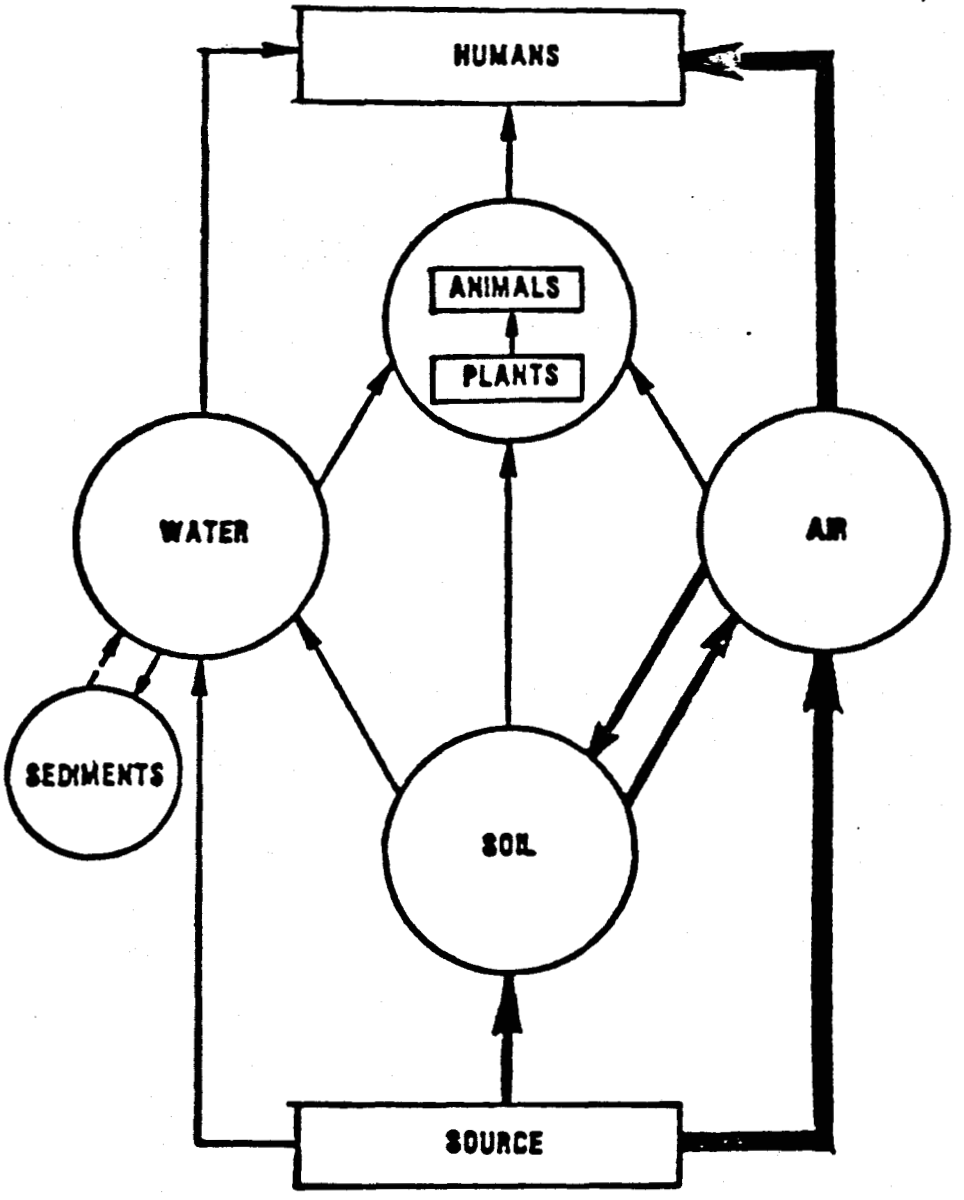
Transuranium elements released to the environment may exist as discrete particles or they may become attached to other materials. The principal modes of transport of these elements from a source to man are by direct airborne movement from the source or by resuspension of previously deposited small particles by the action of wind or other disturbance. Resuspension is a complex phenomenon affected by a number of factors, including the characteristics of the surface, type of vegetative cover, meteorological conditions, and age of the deposit. In general, resuspension will be relatively high immediately after initial deposition, gradually decrease with time, and approach a long-term constant within about one year after deposition.

Transport of plutonium and other transuranium elements through the food chain and subsequent ingestion is generally of lesser importance than the air pathway. Transuranium elements may be deposited on plant surfaces or assimilated through the plant root system. The uptake by plants is relatively small and most animals, including humans, have a high discrimination factor

TABLE 1

INVENTORY OF PLUTONIUM FOR SELECTED SITES IN THE UNITED STATES

LOCATION	APPROX INVENTORY	REMARKS
U.S. (Fallout)	20,000 Ci	Worldwide Pu-238= 17,000 Ci Pu-239=440,000 Ci U.S. average=1.5 mCi/km²
Nevada Test Site (near Las Vegas, NV)	>155 Ci	Nuclear Test Site Surface and Subsurface Tests
Rocky Flats Plant (near Denver, CO)	8-10 Ci	Weapons Fabrication Plant (limited cleanup in progress)
Mound Laboratory (Miamisburg, OH)	5-6 Ci	Pu-238 in sediments in canals
Savannah River Plant (SW part of SC)	3-5 Ci	Pu and higher isotopes production
Los Alamos Lab (NW of Santa Fe, NM)	1-2 Ci	Weapons Development (high levels in remote canyons)
Hanford Site (central WA)	—	Pu Production—Research Facility (high levels in trenches on site)
Oak Ridge Laboratory (east TN near Knoxville)	—	Research & Development Facility
Trinity Site (near Alamogordo, NM)	45 Ci	Site of first atomic bomb test



PRINCIPAL PATHWAYS OF THE TRANSURANIUM ELEMENTS
THROUGH THE ENVIRONMENT TO MAN

Figure 1

against transfer of these elements into body tissues. The solubility of plutonium in water is very low and nearly all plutonium released into lakes and streams is ultimately deposited and sorbed onto sediments. Other possible routes of entry into humans include direct ingestion of contaminated soils and contamination of wounds, but are generally of minor importance relative to the inhalation and ingestion pathways.

Potential health effects caused by the transuranium elements are a function of several biological and physical parameters including the biological retention time in tissue, the type of radioactive emission, and the half-life of the nuclide. For the more important transuranium nuclides, such as Pu-238 or Pu-239, biological retention times are very long and radioactive decay occurs at such a slow rate that uptake of these materials in the human body will result in prolonged exposure of body organs. Many of the transuranium nuclides decay by emission of an alpha particle (ionized helium atom), in a manner similar to radium and other naturally occurring alpha emitting nuclides. Alpha particles are highly ionizing and damaging, but their penetration in tissue is very small (about 40 um). Thus, biological damage is limited to tissue in the immediate vicinity of the radioactive material, and a potential health hazard from transuranium elements in the environment can only result when these materials are inhaled or ingested into the body.

Inhaled particles are initially deposited in various regions of the respiratory tract, where they remain until either cleared or translocated to other body organs. Much of the material deposited in the lung is cleared within a few days, but some of the smaller particles which diffuse into the pulmonary regions of the lung are removed much more slowly and have a biological half-life of a year or more. This may lead to an increase in the risk of lung cancer in exposed individuals. Inhaled transuranium elements may also transfer and be retained in other body organs, and cause cancers of the bone and liver. For the less soluble transuranium compounds, such as plutonium oxide, this will contribute only marginally to the total risk for the inhalation pathway.

Ingestion of transuranium elements generally represents a smaller environmental risk to humans than inhalation. A relatively small fraction of any ingested transuranium element may be transferred to the bloodstream from the digestive tract and deposited in bone, liver, gonadal tissue, and other organs. In most cases, less than one part in ten thousand of the ingested material is absorbed by the body, with the remainder excreted. The risk to individuals as a result of ingestion of transuranium elements is mainly due to potential bone and liver cancers.

A potential risk of genetic damage to the progeny of exposed individuals exists because of possible accumulation of transuranium elements in gonadal tissues. At the dose rates for other organs provided by the interim guidance, this risk is very small compared to the natural incidence of genetic damage.

Other Publications:

The Environmental Protection Agency published a Notice of Intent in the Federal Register, Vol. 39, p. 34098, on September 23, 1974, to Review the Need for Establishing New Rules for Plutonium and Other Transuranium Elements. The Agency held public hearings to gather information in Washington, D.C., on December 10-11, 1974, and in Denver, Colorado, on January 10, 1975. The proceedings of these hearings were published as EPA Document ORP/CSD-75-1.

The Agency published the basis and text of the proposed Federal Radiation Protection Guidance in the Federal Register, Vol. 42, pp. 60956-9, on November30, 1977. The Office of Radiation Programs also published a technical summary document explaining the proposed recommendations (EPA 520/4-77-016), and the Agency has provided responses to all comments received (Technical Report, EPA 520/4-78-010).

The Agency has also published additional related documents entitled "The Ecological Impact of Land Restoration and Cleanup" (Technical Report, EPA 520/3-78-006), "Selected Topics: Transuranium Elements in the General Environment" (EPA/ORP Technical Note CSD-78-1), "Plutonium Air Inhalation Dose (PAID)" (EPA/ORP Technical Note CSD-77-4), and "A Computer Code for Cohort Analysis of Increased Risk of Death (CAIRD)" (Technical Report EPA 520/4-78-012).

A summary of environmental research on transuranium elements, funded by the Department of Energy through calendar year 1979, was published recently as Transuranic Elements in the Environment, Wayne C. Hanson, Editor. It is available as Document DOE/TIC-22800 from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. The book contains an extensive summary of available information, prepared by a number of technical experts, on all aspects of the inventory, distribution in terrestrial and aquatic ecosystems, environmental transport mechanisms and models, and biological effects of the transuranium elements.

Comprehensive reports on plutonium and other transuranium elements prepared by multinational groups of experts have recently been published by the World Health Organization in Nuclear Power—Health Implications of Transuranium Elements (1982), and by the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development in The Environmental and Biological Behavior of Plutonium and Some Other Transuranium Elements (1982). These reports are intended primarily for use by Government officials of member countries, and offer a useful summary of available information in language intended for a nontechnical audience.

Previous Radiation Protection Recommendations:

Federal Radiation Protection Guidance, issued in 1960, stated that "...for the individual in the population, the basic Guide for annual whole body dose is 0.5 rem. This Guide applies when the individual whole body doses are known. As an operational technique, where the individual whole body doses are not known, a suitable sample of the exposed population should be developed whose protection guide for annual whole body dose will be 0.17 rem per capita per year. It is emphasized that this is an operational technique which should be modified to meet special situations," and further recognized that "...the guidance does not cover all phases of radiation protection, such as internal emitters".

Federal Radiation Protection Guidance, issued in September 1961, provided recommendations applicable to certain internal emitters, specifically radium-226, iodine-131, strontium-89 and strontium-90. It recommended that... "The radiological health activities of Federal agencies in connection with environmental contamination with radioactive materials be based, within the limits of the agency's statutory responsibilities, on a graded series of appropriate actions related to ranges of intake of radioactive materials by exposed population groups". The Guidance contained the following table of Graded Scales of Actions:

Range I	Periodic confirmatory surveillance as necessary.
Range II	Quantitative surveillance and routine control.
Range III	Evaluation and application of additional control measures as necessary.

The International Commission on Radiological Protection (ICRP) has recently issued general guidance on limits of risks deemed acceptable by the general public for exposure to ionizing radiation. In ICRP Publication 26 (Paragraph 118) it states that "from a review of available information related to risks regularly accepted in everyday life, it can be concluded that...a risk in the range of 10^{-6} to 10^{-5} per year would be likely to be acceptable to any individual member of the public."

Rationale for Recommendations:

The objectives of the recommendations are: to provide uniform guidance to all Federal agencies on dealing with environmental contamination by transuranium elements, to provide a technical decision basis for possible remedial actions, and to provide adequate information to the public.

The recommendations are intended to address the problem of the long-term risk from environmental contamination by the transuranium elements and are based on the following principles: that continuing exposure from residual contamination by the transuranium elements should be as small as reasonably achievable, that the dose rates should not exceed the generally applicable radiation protection guidance for exposures, that increasing risks require progressively greater protective measures, and that implementation actions be practical in terms of feasibility and overall economic requirements.

In order to establish a perspective on the residual levels of transuranium elements in the general environment, the Agency first reviewed the levels of existing environmental contamination by transuranium elements at all major known sites in the United States. Contour maps were used to evaluate the areas contaminated above various soil contamination levels at these sites. A reference soil contamination level of 0.2 uCi/m^2, which can be approximately

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equated to an inhalation or ingestion risk of one per million per year for a continuously exposed individual, was used as a basis for comparison. We determined that only small areas outside the limits of sites controlled by the Federal government exceeded this reference level, but that there were relatively large areas of localized residual contamination below that level. We therefore concluded that it was not feasible to establish a dose rate limit substantially lower than that required by the existing situation.

We further considered derivation of general recommendations for possible future incidents of contamination. We determined that such recommendations must recognize that one is dealing with many unknown factors and that one must provide discretion to the implementing agency. Therefore, our proposal specified that the objective of limiting the long-term risk to persons from such unplanned releases should be equivalent to that deemed acceptable for the existing sites, and to further reduce all doses to as-low-as-reasonably-achievable (ALARA).

In revising these recommendations, we gave increased emphasis to the need to provide specific advice on how to deal with possible future incidents of environmental contamination by the transuranium elements. Accordingly, the revised recommendations provide a range of dose rate limits and corresponding action levels as a guide for site-specific actions. Such a range of action levels is deemed preferable to a single numerical limit in order to provide for flexibility of implementation, to accommodate uncertainties, to facilitate application of optimization principles, and to specify a graded series of intervention measures.

The revised recommendations adopt the general approach of graded action levels corresponding to increments of increased risk as stated in the Federal Radiation Guide of 1961 for internal emitters. The upper bound of Range I is intended to assure that dose rates to persons in a critical segment of the

population are well below the current recommendations of national and international radiation protection organizations, the upper bound of Range II corresponds to the limits of the radiation protection guides, and Range III would allow exceeding the limits for a short time when necessary. The revised recommendations are intended to assure that the contribution of dose rates from exposure to the long-lived transuranium elements is sufficiently small to be accommodated within the normal radiation protection guides, and that the contribution from a single source be well below the overall limit from all sources. In accord with general radiation protection principles, implementation of the appropriate protective actions is expected to result in doses as-low-as-reasonably-achievable (ALARA).

The recommendations are given in terms of dose rates to persons in a critical segment of the population, rather than in terms of residual contamination levels. This is in accord with ICRP Publication 26, which states (Paragraph 85) that "the basis for the limitation of individual exposures...is the limit for the weighted mean whole body dose equivalent and not the derived limits or levels by which the dose is controlled. The actual doses received by individuals will vary depending on factors such as differences in their age, size, metabolism, as well as variations in their living habits and environment. With exposure of members of the public it is usually feasible to take account of these sources of variability by the selection of appropriate critical groups within the population provided the critical group is small enough to be relatively homogeneous with respect to age, diet and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose equivalent, and the [International] Commission [on Radiological Protection] believes that it will be reasonable to apply the appropriate dose-equivalent limit for individual members of the public to the weighted mean dose equivalent of this group."

The upper bound of Range I limits doses to the primary target body organs for high-LET (alpha) radiation, including consideration of the added risks associated with transmigration to other organs, to an equilibrium dose rate of 1 mrad/year to pulmonary lung or a dose rate of about 3 mrad/year to aggregate bone. This corresponds to a whole-body dose equivalent of about 10 mrem/year, or about one-tenth of the radiation protection guide, and is equivalent to a risk limitation of one-per-million per year of exposure. In accord with the results of public hearings and comments, we believe that a maximum risk of one-per-million per year from residual transuranium element contamination is sufficiently small to be generally acceptable to allow for unrestricted occupancy and use of lands.

The recommendation that residual contamination be reduced to those specified by Range I to result in dose rates equivalent to a small fraction of the radiation protection guide is primarily intended to minimize a need for continuing surveillance of a large population group. It is not intended to imply that exceeding the limit of Range I leads to unacceptable risks for persons in the general population, but rather should be considered to represent a convenient mechanism for implementing the recommendations and to emphasize that long-term exposures equivalent to a large fraction of the total radiation protection guide should be avoided to the extent practicable. This is in accord with the views of most radiation protection authorities that there is no level of "safe" exposure to radiation, so that determination of an appropriate limit for a specific source or activity becomes a matter of judgment based on appropriate factors.

The dose rates specified for Range I are based, in part, on a recognition of what can actually be achieved under realistic conditions. Limitations are imposed by the capability of current field measurement instruments, by the increasing difficulty of identifying small areas of excess contamination at low concentration levels and, ultimately, by the excessive costs of further risk reduction.

The limit specified for Range II provides that dose rates to persons in the critical segment of the population not exceed the radiation protection guide limit of 100 mrem/year from all sources (except background radiation and medical exposures), and that all exposures be as-low-as-reasonably-achievable (ALARA). It is intended that the level of remedial actions within this range be in direct relation to the overall risks to the exposed population, and that the higher the dose rate from residual transuranium element contamination the more effort should be expended for public health protection. Dose rates in excess of those specified for Range II (to a limit of 500 mrem per year) are designated as Range III. These may be allowed where necessary when the exposure is temporary and not continuous, but require maximum protective measures and followup of the exposed population.

The recommendation that the annual average whole-body dose equivalent rate not exceed 100 mrem per year for all sources except background radiation and medical exposures is consistent with recommendations by the ICRP for limiting the radiation dose rate to a continuously exposed identified individual in the general population. Appropriate dose rate limits for specific body organs may be derived to correspond with these risk limits, and should consider both the different modes of intake into the body and the cumulative risks from translocation and retention in more than one organ.

A comparison with other risks is useful in providing a perspective understandable to most people. However, such a comparison can provide only a descriptive basis for individual judgments and does not provide an analytical decision method. The major categories of risks leading to premature death (in order of decreasing probability) include: disease, accidents, and natural catastrophes. A tabulation of commonly encountered risks and their probability of occurrence (averaged over the U.S. population) is shown in Table 2. It should be noted that the risk to a specified critical group (e.g., persons living in an area subject to hurricanes) may be much greater than that shown here.

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TABLE 2

PROBABILITY OF DEATH BY VARIOUS CAUSES
(U.S. Population Average for 1978)

Cause	Total Number of Deaths	Individual Risk (Probability/yr)[a]
Accidents		
Motor Vehicle	52,411	2.4×10^{-4}
Air Transport	1,880	8.6×10^{-6}
Railway	602	2.8×10^{-6}
Falls	13,690	6.3×10^{-5}
Fire	6,163	2.8×10^{-5}
Drowning	5,784	2.7×10^{-5}
Industrial	5,168	2.4×10^{-5}
Electrocution	984	4.5×10^{-6}
Explosion	562	2.6×10^{-6}
Firearms	1,806	8.3×10^{-6}
Diseases		
Cardiovascular	964,000	4.4×10^{-3}
Malignancies	396,720	1.8×10^{-3}
Influenza/Pneumonia	58,230	2.7×10^{-4}
Diabetes	33,800	1.6×10^{-4}
Natural Events		
Lightning	160	7.3×10^{-7}
Tornadoes	118[b]	5.4×10^{-7}
Hurricanes	90[c]	4.1×10^{-7}

(a) Based on total U.S. Population
(b) 1953-75 average
(c) 1901-71 average

For the same reason, it is useful to view an objective for radiation protection by comparison with the unavoidable exposure received from natural background radiation. All persons are exposed to radiation which consists of cosmic rays and the radiation from naturally occurring radionuclides (such as uranium) which exist in the general environment. The annual dose from this background radiation varies by location, with an average of about 100 millirem per year to persons in the continental United States. The average risk from natural background radiation is of the order of 10^{-5} per year.

The implementation requirements assure that the recommendations will be applied conservatively. ICRP Publication 26 states (Paragraph 120) that "...due to the maximizing assumptions usually made in selecting critical groups, the doses actually received by the most highly exposed individual will in most cases be considerably lower than the doses postulated for the critical group." This assures that the average risk to all persons in the general population will be much lower than that for the critical segment. We have further superimposed the requirement that the risk for exposure to environmental contamination from the transuranium elements be calculated conservatively for lifetime occupancy, so that it would be unlikely for any person to actually be subjected to the maximum specified risk level.

The recommendations provide for a cost-benefit analysis in optimizing the radiological protection of the public. While the primary emphasis of these recommendations is on minimization of the dose to individuals, consideration of the collective dose, which gives a measure of the total detriment to the population, is useful in an assessment of the costs which society may be willing to bear for remedial actions intended to provide a reduction of risks. Such an evaluation is part of the system of dose limitation recommended by the International Commission on Radiological Protection, which includes justification, limitation, and optimization, and is given in ICRP Publication 26. To determine whether a further reduction of exposure from a given level is desirable, the ICRP suggests that the

value of any increased benefit achieved by such a reduction in exposure should be weighed against the cost of obtaining this reduction. The long radioactive half-lives of some of the transuranium elements make the evaluation of the total detriment over the entire time of persistence in the environment, to the extent practicable, a question of considerable importance. While such a procedure is useful in decisions on risk management, it is not the only consideration and risk management must involve a balanced judgment of all appropriate factors.

Costs of Remedial Actions:

We have also reviewed the costs of implementing these recommendations. We concluded that the total costs of implementation for existing areas of contamination will be small but would increase very rapidly, with little compensating gain in public health protection, if lower dose rate limits were considered. The total costs of implementation for possible future incidents are indeterminate, and will vary with location, contamination level, and other factors.

Two categories of situations are addressed by these recommendations: (1) existing plutonium and other transuranium element contamination at a few sites where the contamination is stabilized and the distribution and soil concentration are well characterized, and (2) possible future releases (from operating facilities, nuclear weapons accidents, etc), where neither the magnitude of release nor its location can be known in advance of the occurrence.

Optimization of protection requires minimization of both the individual doses to persons in a critical group and of the collective dose to the entire exposed population over the entire time of persistence in the environment. It may include economic, engineering, and other applicable considerations. These constitute the basis for an evaluation of the options for protective actions on a site-specific basis.

Estimated costs of remedial actions were discussed in Chapter 4 of the "Response to Comments" document published by EPA. A detailed evaluation of costs entitled "Department of Energy Comments on Decontamination Costs" is reproduced as an annex to that publication. Costs for remedial actions can be expected to vary by location, contamination level, and other factors and may range from several hundred to a half-million dollars or more per acre in 1980 dollars, depending on the method(s) used and the type of storage required. There are several general techniques for restoring contaminated lands to unrestricted use: (1) stabilization and selective removal of surface soil; (2) plowing or other dilution methods; and (3) removal of all surface soils and transportation to another location for final disposal. In general, costs for most cleanup methods would range from several hundred to about $20,000 per acre if relocation and disposal of soils is not required. Disposal in a near-surface regional facility is estimated to cost from $150,000 to $300,000 per acre, and disposal in a geological repository up to $500,000 or more per acre. Remedial actions must be chosen in relation to the existing contamination levels and other conditions, with minimal requirements for soil contamination levels less than about 1 uCi/m^2 and progressively more stringent actions as the level increases.

There are four Federal sites in the United States that presently have transuranium element contamination above ambient levels beyond their boundaries. These include the Rocky Flats Plant in Jefferson County, Colorado, Mound Laboratory in Miamisburg, Ohio, Nevada Test Site in southern Nevada, and Trinity Test Site near Alamogordo, New Mexico. The majority of all contamination released is confined within areas under the direct control of the Federal government, which imposes restrictions on the access and use of these areas. Relatively small amounts of transuranium element contamination exists outside the boundaries of these sites on lands generally accessible to the general public and will require further evaluation.

Evaluations of the potential costs of remedial action at these existing sites of contamination excluded those areas currently under the direct control of the Federal government. Use restrictions may have to be applied in some instances, with the recognition that retention of institutional controls cannot be assumed to continue over the very long periods a potential hazards may continue to exist. The size of the contaminated areas at these locations which may need remedial action is very small, the levels of contamination in unrestricted areas are low, and it can be expected that only minimal remedial actions would be required. The major costs of implementation at these sites will be those of confirmatory evaluations.

The economic impacts of applying these recommendations to possible future incidents of contamination are represented by the differential costs, which represent only the costs above those which would be incurred in the absence of this guidance. Remedial actions will generally be selected on the basis of achieving maximum reduction of residual contamination to achieve long-term public health protection and to alleviate public concern.

If the recommendation that "compliance....should be achieved within a reasonable period of time" is followed, this can be expected to reduce the costs of implementation for possible future incidents of contamination. For most circumstances, one would therefore expect that any cleanup required for new incidents of contamination would be limited to the top 2 or 3 cm of soil and vegetation, and minimize the amount of material to be disposed of in off-site repositories.

A final consideration applicable to any remedial action program is the possibility that disturbance of the environment might do long-term harm. The Agency has examined this aspect, and published an extensive analysis entitled "The Ecological Impact of Land Restoration and Cleanup," EPA Technical Report 520/3-78-006. This report examines in detail the consequences of disturbing some of the more significant ecosystems and their recovery rates. Such an

evaluation is essential prior to the initiation of any major remedial action program. It can therefore be concluded that consideration of all factors involved in deciding on the feasibility, type, and extent of cleanup is needed prior to initiation of such actions, and that such decisions must be made in the context of an overall balancing of the costs and benefits.

Biological Effects:

In deriving these recommendations, the calculation of risks resulting from radiation exposure was based on the assumption that there is some possibility of harm no matter how small the amount of absorbed radiation. The magnitude of the added risk is assumed to be proportional to the dose received, with different response characteristics for various body organs. The risk at very low dose levels is assumed to be directly proportional to the damage actually observed at much higher dose levels. Health risks resulting from radiation exposure were estimated mostly by using models and recommendations that were published by the Advisory Committee on the Biological Effects of Ionizing Radiation of the National Academy of Sciences (NAS-BEIR Committee) in its reports entitled The Effects on Populations of Exposure to Low Levels of Ionizing Radiation (1980), and Health Effects of Alpha-Emitting Particles in the Respiratory Tract (1976).

The biological effects of radiation are somatic and genetic, and lead to an increased risk in cancer to those exposed and an increased risk of defects to future generations. For an internal emitter, calculation of a specific risk to persons in the general population requires use of complex mathematical models which relate mode of intake, internal distribution of the radionuclides, modes of decay, absorption of energy in different tissues, and the resultant risk of cancer or other defects in body organs. The technical basis for an evaluation of "The Dose And Risk To Health Due To The Inhalation And Ingestion Of Transuranium Nuclides" was discussed in Annex III of the technical summary document EPA-520/4-78-010 and in Section 6 of the "Response to Comments" document (Technical Report EPA 520/4-78-010).

Inhalation and ingestion of transuranium elements results in deposition in the body. Inhalation may cause lung cancers, and ingestion may cause bone and liver cancers. Translocation to other body organs may also occur. For a person continuously exposed over an entire lifetime at the environmental level resulting in the dose limits equivalent to Range I of these recommendations, the added risk of developing a cancer would be about 5 per 100,000 per lifetime, or 1 per million per year. This can be compared with a normal expectation of about 16,000 cancer deaths in the lifetime of a cohort of 100,000 persons, or a risk to the individual of 2000 per million per year. Genetic damage may result from retention of transuranium elements in gonadal tissue. For the extreme case of exposure of both parents at the recommended somatic risk limit for 30 years, each 100,000 live births may produce from 1 to 20 genetic defects in the first generation. This can be compared to the approximately 6,000 genetic defects normally observed in 100,000 live births.

Recent advances in radiation dosimetry have further refined the models used to describe the migration of radionuclides to bone and the resultant risk. As a result, the recommendations of the International Commission on Radiation Protection (ICRP) are now stated in terms of dose limits for bone surfaces and bone marrow instead of a single average dose limit for the entire skeletal bone mass (ICRP Publications 26 and 30). In order to accommodate both the previous and current models, we note the option of using either model in implementing these recommendations.

Inhalation and/or ingestion of the transuranium elements results in a cumulative risk by virtue of long biological retention times and by additional translocation to other body organs. Therefore, the total risk to an exposed person relates to the sum of all organ doses over an entire lifetime. For continuing exposure at the same ambient level, an equilibrium dose to the lung is reached in several years while the dose to bone continues to increase with time. The recommendations specify the dose rate limits for any single year during the lifetime of an exposed individual. On a conservative basis, the

reference dose rate is assumed to apply to the 70th year for constant cumulative exposure to a long-lived radionuclide with long retention time. The dose rate in any other year will then be lower than that for the reference year. The dose rate in the 70the year for lifetime exposure at a constant annual intake can be shown to be equivalent to the integrated lifetime committed dose for the same annual intake incurred during the first year. The ICRP (in Report No. 26), has recently recommended that "when the...exposure results from environmental contamination, the individual and collective annual dose equivalents may rise to a maximum over a period of years even if (the exposure) continues at a constant level. Their maximum corresponds either to the achievement of an equilibrium condition or to the level resulting from the period of application of the practice. It is this maximum of the average dose equivalent in the critical groups that should be compared with the corresponding dose-equivalent limit." These recommendations are in accord with the radiation protection concepts for long-lived radionuclides as proposed by the ICRP, and are intended to be used in an analogous manner.

The principal change made as the result of updated information involves introduction of dose and risk estimates for red bone marrow (leukemia) and endosteal bone surfaces (bone cancer). In addition, risk estimates for internal organs have been revised in accord with the recommendations published in 1980 of the NAS-BEIR Committee (popularly known as the BEIR 3 Report). Lung inhalation dosimetry is in accord with the recommendations of ICRP Reports 19 and 30.

For an equivalent dose to skeletal bone in the 70th year, the combined risks estimated by use of BEIR 3 for the doses to red bone marrow and endosteal bone surfaces increase by a factor of about three over those estimated for skeletal bone by use of BEIR 1. However, it should be noted that the current risk estimates for leukemia for alpha radiation are based on low-LET radiation exposures and may be high by as much as a factor of ten. Similarly, the

estimate of risks from doses to liver based on BEIR 3 increase by a factor of about three. The risks of doses to the lung estimated by use of BEIR 3 are similar to those derived from BEIR 1.

The revised risk estimates would indicate that the dose rate recommendations for skeletal bone (and for red bone marrow) for the ingestion mode of exposure should be reduced by a factor of 3-4 from that proposed earlier in order to achieve a similar objective in terms of risk to persons in a critical segment of the population. However, in view of the substantial uncertainty in the estimate for leukemia risk, we believe that it would be most useful to continue to use the dose rate for "bone" as proposed but add a note of caution on its ultimate acceptability. We believe that public health protection would not be compromised by such interim advice, and that the numerical objectives represent a projected risk not appreciably greater than 10^{-6} per person per year. For the inhalation mode of exposure, the total risk for equivalent doses remains about the same as the previously published estimates, but the distribution of risks to the several body organs is substantially changed.

Although the basis and derivation are different, it may be of interest to compare the derived annual limit of intake (ALI) for occupational exposures, as recommended in ICRP Publication 30, with the corresponding values for this guidance. The basis for the ALI's is a committed dose equivalent of 5 rem, while the basis for the limits in this guidance is the dose rate to bone for the 70^{th} year of intake. The derived annual limit of intake (ALI) for Pu-239, given in ICRP Publication 30 for occupational exposures and based on a gut transfer factor of $f_1 = 10^{-4}$, is 3×10^5 Bq/year (8 uCi/year). The corresponding limiting values for this guidance, based on $f_1 = 10^{-3}$ for adults in the general population as recommended in ICRP Publication 48, are 0.08 uCi/year (3×10^3 Bq/year) for Range I and 0.8 uCi/year (3×10^4 Bq/year) for Range II.

Scope of Guidance:

The interim recommendations are intended to provide uniform guidance to all Federal agencies and to the States on dealing with incidents of environmental contamination by the transuranium elements. They are to be used as realistic criteria for radiation protection of persons in the general population for the specific case of potential long-term exposure to transuranium elements from existing or possible future incidents of environmental contamination, and should be interpreted in terms of the potential exposure of present or possible future persons. The objective of remedial actions should be restoration permitting full-time occupancy. The very long radioactive half-lives of several of the transuranium elements and their known persistence in the biosphere makes it important to remove these hazardous materials from the accessible environment to the extent feasible. Remedial actions should accomplish a permanent, rather than short-term, reduction in the potential risk to persons in the general population. Institutional controls, such as fencing or land-use restrictions, cannot be assumed to endure for more than a few hundred years. We have therefore concluded that restrictions on occupancy or land use are generally not appropriate for long-term control and cannot be relied on to provide the necessary protection to future generations. Decisions on temporary restrictions must be made by the implementing agency on a site-specific basis, with full consideration of all adverse effects.

The recommendations are limited to evaluation and possible remedial actions appropriate to stabilized contamination. They do not apply to the transient period during and immediately following an accident when protective actions generally defined by emergency response criteria are appropriate. It is recommended that stabilization and other actions intended to minimize the consequences of the contaminating event be initiated as quickly as possible, and that remedial actions be completed within a reasonable length of time.

The recommendations apply to all persons who reside outside the boundaries of a Federally owned, operated, or licensed radiological facility or who are not otherwise under the full and direct radiological control of a Federal agency. The recommendations are not applicable to occupational exposures, which are subject to different considerations.

The recommendations apply only to the transuranium elements and only to existing or possible future surface contamination. It is not appropriate to use the numerical dose rate limits for pulmonary lung and for bone given in these recommendations, or any other limits derived from these, and apply them to any other radionuclides without detailed evaluations as to their applicability, including analyses of pathways, dosimetry, and risk relationships.

Implementation:

Implementation of the interim recommendations is the responsibility of the Federal agency under whose jurisdiction the facility which caused the environmental contamination operates, or of the Federal agency whose operations otherwise cause the environmental contamination. Implementation includes determining both the actual or potential hazard to people and instituting remedial actions where required.

In applying these recommendations, Federal agencies should consider the full range of options for remedial actions and determine both the effective risk reduction and incremental costs relative to a base case. An evaluation of the feasibility and costs for such a range of options should be included as part of the documentation of the decision process. The determination of the appropriate risk limits for each incident of contamination should be carried out on a site-specific basis, and decisions on the focus and extent of remedial actions should be made on the basis of long-term public health protection.

Explicit guidance on implementation of these recommendations is not provided, both to allow for flexibility in application and to avoid imposition of criteria not appropriate to a specific site or condition. It is intended that these recommendations be interpreted by technical experts for each site of contamination, and that they not be applied on a formalistic basis. The development of new information on environmental pathways, or the consideration and importance of site-specific parameters, are examples of areas where the judgment of experts is required in applying these recommendations.

Specific implementation directives for remedial actions, in a report entitled "Nuclear Weapon Accident Response Procedures (NARP) Manual," have recently been provided by the Defense Nuclear Agency of the Department of Defense (Report DNA 5100.1, January 1984). This manual provides valuable information on administrative procedures and technical data applicable to an emergency response situation. In addition, the United States undertook a large-scale remedial action operation on the Enewetak Atoll during the 1970's, with the objective of resettling the native population of a former weapons test site. Although the situation was unique, the operation provided valuable experience applicable to future remedial actions. The Department of Energy provided cleanup objectives for the transuranium elements similar to those recommended here, and applied these to islands categorized by use and occupancy. The Environmental Protection Agency has recently published detailed general procedures for remedial actions in the "National Oil and Hazardous Substances Pollution Contingency Plan". Other criteria and recommendations developed for specific cleanup operations have also been published elsewhere and should be reviewed prior to initiation of any future actions.

Under provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, it is required that notification of releases that are equal to or greater than a designated reportable quantity (RQ) for that element be made to the National Response Center. Section 102(a) of CERCLA authorizes the Administrator of the

Environmental Protection Agency to designate as hazardous substances those, which when released into the environment, may present a substantial danger to the public health or welfare or the environment, and to publish listings of adjusted reportable quantities for such substances. A listing of the reportable quantities for the transuranium elements has been published, and Federal agencies must report releases to the general environment in excess of the reportable quantities for the specified radionuclides.

Implementation of the recommendations may be facilitated by direct measurement of ambient environmental concentrations. ICRP Publication 26 states (Paragraph 82) that "In many practical situations it will be convenient to make use of a derived limit, calculated with the aid of a model, which provides a quantitative link between a particular measurement and the recommended dose-equivalent limit or intake limit. In deriving such a limit the intention should be to establish a figure such that adherence to it will provide virtual certainty of compliance with the [International] Commission [on Radiological Protection] recommended dose-equivalent limits. However, failure to adhere to the derived limit will not necessarily imply failure to achieve compliance with the Commission's recommendations and may require only a more careful study of the circumstances."

Numerical values for levels of soil or air concentrations have been derived which can reasonably be expected to result in dose rates less than the threshold concentration given in these recommendations. On the basis of limited data available for several existing sites, a soil contamination level of 0.2 uCi/m^2, for samples collected at the surface to a depth of 1 cm and for particle sizes under 2 mm, would establish a reasonable "screening level" for this purpose. Similarly, an air concentration "screening level" of 1 fCi/m^3 for alpha-emitting transuranium nuclides (based on an activity median aerodynamic diameter [AMAD] of 1 um) may be used under most circumstances. Using such derived numerical values can reduce the size of land areas requiring evaluation and minimize the number of measurements needed.

Areas which do not exceed the "screening level" generally would be considered in compliance with the recommendations; those that exceed it would require more intensive evaluation to determine the actual dose rates to exposed persons.

It should be noted that soil characteristics differ greatly in different locations and that measurements of surface and subsurface soil contamination levels, and their interpretation in terms of predicting possible migration to people, are subject to great variability and uncertainty. Therefore, it is essential that site-specific information and local characteristics be given full consideration in assessing the potential impacts of transuranium element contamination. Federal agencies can generally show compliance with the recommendations by publishing the results of measurements of the concentration of transuranium elements in air and/or soil, and calculating the dose rates to internal organs of persons living in the vicinity of a specified site.

It can generally be expected that a variety of techniques could be used to achieve reductions in risk to exposed persons. An economic evaluation can be used to identify the technique or combination of techniques which will achieve a specified objective at least total cost. Monetary costs, environmental costs, and other non-quantifiable costs should all be considered in the evaluation of each alternative combination of possible remedial actions.

Environmental Assessment:

Under the provisions of the National Environmental Policy Act of 1969, it is intended that every major Federal action be examined in terms of projected impacts and that all available alternatives be considered. The purpose of such an analysis is to compare the options in terms of the broad range of projected health, sociological, economic, and environmental impacts.

The guidance is to be implemented on a site-specific basis, and does not include recommendations on specific methods of cleanup and restoration. Such methods are to be determined for each site by consideration of the effectiveness of the cleanup techniques, the cost-benefit evaluation, and the specific environmental impacts. The range of total impacts must be evaluated separately and independently for each proposed major remedial action.

Under Section 102(2)D of the National Environmental Policy Act of 1969, agencies are required to study, develop, and describe appropriate alternatives to the proposed or recommended courses of action. The purpose is to analyze the environmental effects, benefits, costs, risks, and related issues, so as not to limit options which might better advance environmental quality or have less detrimental effect. Examples of such alternatives are those of taking no action, of postponing action pending further study, or of taking actions of significantly different nature which could provide similar benefits with less severe environmental impacts.

The possible impacts of a remedial action will vary according to the nature and scale of the method used for cleanup and restoration of a contaminated area, and may be particularly sensitive to the location. The primary impacts of most remedial actions will generally be some temporary disruption of normal activities on and near the site, temporary impairment of air and water quality, and possibly significant effects on flora and fauna.